Advanced Brain MR Imaging

Surgical Planning of Tumors with fMRI and DTI

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Recent significant technical advances in neuroimaging modalities are changing the standards for preoperative imaging and surgical planning of patients with a brain tumor. The goal of every neurosurgical procedure is to maximize tumor resection with minimal permanent postoperative neurological morbidity. The extent of resection depends on tumor's location, size, presumed diagnosis on morphological MRI, age and medical conditions of the patient. Advances in neurosurgical methods, including frameless navigational systems, intraoperative imaging with ultrasonography or intraoperative MR imaging (iMRI), and electrostimulation mapping techniques (ESM) enable the neurosurgeon to optimize cytoreduction. Neuronavigation systems assist the neurosurgeon in planning the approach to the tumor and in evaluating the extent of cytoreduction.

Resection of a lesion near eloquent functioning cortex and white matter tracts requires a detailed understanding of functional anatomy and its relationship to surrounding cortical gray matter and white matter connections. Intraoperative ESM of cortical and subcortical tissue in and around a tumor has been used to identify functional tissue. ESM is the only technique available that provides reliable identification of subcortical tracts carrying motor, sensory and language informations.

Functional MRI (fMRI) has been used in the presurgical localization of eloquent gray matter structures near brain tumors. Multiple fMRI studies have shown that small changes in blood oxygenation occur in

eloquent cortex during execution of a task. Unfortunately, several uncontrolled biological and physiological variables make the interpretation of fMRI studies sometimes difficult. Loss of neurovascular autoregulation in areas of functioning brain tissue adjacent to the tumor may be the cause of false negative results. The difficulty to differentiate homotopic reorganization from pseudo-reorganization may be another cause of confusion.

The accuracy of the BOLD response in mapping eloquent functional cortex has been evaluated using intraoperative ESM or magnetoencephalography (MEG) as a gold standard. Many studies have shown that fMRI is pretty good to identify the primary motor (PMC), primary sensory (PSC) and primary visual cortex. It is good but not perfect to map the language network. fMRI is not accurate enough to lateralize memory functions. When fMRI results are discordant it is very important that the neuroradiologist recommend the use of alternate techniques such as ESM, MEG, Wada to confirm functional relationships. A systematic follow-up of the neurological exam of the patient post-surgery is also essential in evaluating the accuracy of fMRI. The neuroradiologist must acknowledge the limitations of the technique during analysis of the results.

Another limitation of fMRI is its insensitivity to functional white matter tracts that may be within or around the neoplasm. Diffusion Tensor Imaging (DTI) has the potential to provide this type of information preoperatively. DTI is based on the principle of anisotropic diffusion of water in axons and compacted fiber bundles. The spatial orientation of major (compacted) fiber tracts can then be represented with color-coded directional maps. White matter tracts with a craniocaudal orientation are displayed in blue; tracts with a left/right orientation in red; tracts with an anterior/posterior orientation in green. The

accuracy of DTI-based color-coded maps to identify functioning white matter surrounding an infiltrating neoplasm is currently under investigation. It has been proposed that the combination of fractional anisotropy (FA) and orientation measures provided by DTI allows characterization of white matter tracts in four categories: displaced, edematous, infiltrated and destroyed. These informations also may be very useful to the neurosurgeon.

Studies combining fMRI and DTI-based tractography use ROI defined by fMRI instead of *a priori* ROI to look for white matter bundles connecting activated cortical areas of a specified network. The main clinical indication of combining fMRI with DTI is a cerebral neoplasm located within or adjacent the primary motor or language areas. Eloquent structures of the motor network include the precentral and postcentral cortex (motor strip), the Supplementary Motor Area (SMA), and the pyramidal tracts connecting the motor strip throu the posterior limb of the internal capsule to the brainstem. Eloquent cortical areas and fiber bundles that form the language network are the inferior frontal gyrus (IFG, that is also known as Broca's area), the dorsolateral prefrontal cortex (DLPFC), the anterior cingulate, the posterior superior temporal gyrus (STG, that is also known as Wernicke's area) and the uncinate fasciculus.

The limitations of fMRI and DTI in preoperative imaging of brain tumors and other issues related to technical and clinical validation of these techniques before they can be translated into clinical practice will also be addressed.

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Suggested readings

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